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(71) Applicant: ANUTECH PTY. LIMITED
Acton, ACT 2601 (AU)

(72) Inventors:
- Kaneff, Stephen
  Red Hill, ACT 2603 (AU)
- Whelan, Robert Edgar
  O'Connor, ACT 2601 (AU)

(74) Representative:
Valentine, Francis Anthony Brinsley
REDDIE & GROSE 16 Theobalds Road
London WC1X 8PL (GB)

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(54) Hydraulic control of the rotation of a body about an axis

(57) Rotation of a body about an axis (82) is achieved by moving an arm (81) extending from the body. The mechanism for moving the arm includes a hydraulic ram having a ram cylinder (84), which is connected to the arm (81), and a ram rod (86). The end of the ram rod (86) which is remote from the ram cylinder is engageable with one of series of anchor members (85a, 85b, 85c) mounted on a platform, in a circle or on an arc of a circle. The end of the ram rod (86), when disengaged from an anchor member, is guided to an adjacent anchor member along a circular, or arcuate, guiding means (89). This mechanism is suitable for the rotation of a support frame (15) of a large dish (12) of a solar collector antenna about a vertical axis (20), as part of the arrangement whereby the dish support frame (15) is moved - for example, to enable the dish to track the sun.

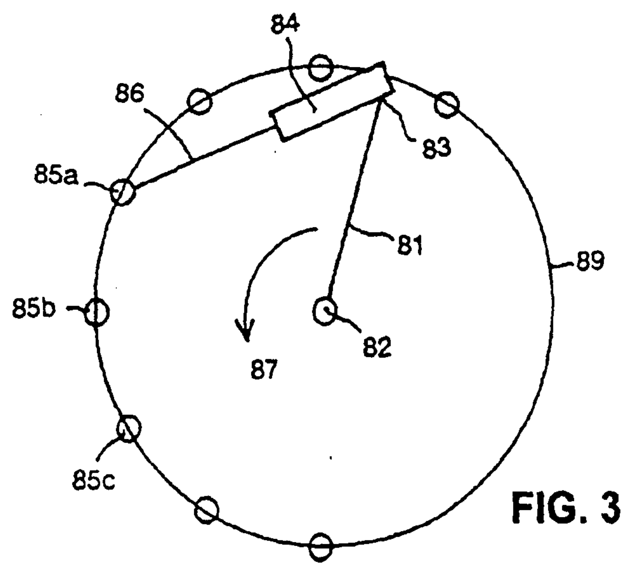

FIG. 3

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Description

Technical Field

[0001] This invention concerns the rotation of rigid structures about an axis. This invention was developed to control the rotation of a structure on which a large dish antenna - of the type used for radio telescopes, solar collectors, satellite communication, and the like - has been mounted. In this application, the invention is part of the arrangement for controlling the orientation of the dish antenna. In view of this historical background, the description of the invention in this specification will concentrate on this application of the invention. However, it will be appreciated that the present invention is not limited in its application to the rotation of structures which support large dish antennas.

Background to the Invention

[0002] Dish-like antennas which are used as, for example, receivers of signals from satellites, solar collectors and radio telescopes, utilise a reflecting dish to focus electro-magnetic radiation upon a receiver. The dish comprises a reflective or conductive surface which is mounted on a rigid frame. The dish, with its supporting frame, is manipulated by one of a number of conventional techniques, discussed below, to point continuously to the object from which the antenna receives electromagnetic radiation.

[0003] A problem with large dish antennas is associated with the rotation of the antenna structure about a vertical axis, which is an integral part of the "tracking" of the antenna to keep its line of sight directed at a particular object (the sun, in the case of a solar collector). Normally, this rotation of the antenna structure is effected using a motor which drives a pinion. The pinion engages with an arcuate or circular toothed track. The motor, which is electrically or hydraulically powered, drives the pinion through a reduction gearbox, so that the antenna is rotated continuously, yet slowly, about a vertical axis.

[0004] Such electric or hydraulic motors, with their reduction gearboxes, are expensive components. Furthermore, should there be a power failure, provision must be made to "off steer" the antenna rapidly to avoid potential damage to the receiver of electromagnetic radiation. The "off-steering" device requires a back-up power supply to enable it to function in an emergency. The back-up power supply is usually a bank of batteries, which require regular maintenance as well as adding to the capital cost of the antenna installation.

Disclosure of the Present Invention

[0005] It is an objective of the present invention to provide a new mechanism for rotating a body such as a large dish antenna.

[0006] In one realisation of the present invention (in its application to a large dish antenna) an arm which extends from the vertical axis of rotation of the base frame of an antenna (this arm is rigidly connected to or constitutes a component of the base frame of the antenna, on which a dish supporting frame is mounted) to the cylinder of a double-acting hydraulic ram. The free end of the rod of the hydraulic ram is connected to one of a plurality of anchor members which are rigidly mounted on the earth or on the platform on which the base frame is mounted. The anchor members are approximately equispaced around a circle having its centre at the vertical axis of rotation of the antenna. When the hydraulic ram is contracted, it pulls the end of the arm towards the anchor member to which the end of the ram rod is connected, and thus rotates the antenna about its vertical axis. At a predetermined point in the contraction of the ram, the contraction ceases, the arm is locked in the position it has reached, and the free end of the ram rod is disconnected from the anchor member. Then the ram is expanded and the free end of the ram rod is guided to the next anchor member of the circle of anchor members. Upon arrival at the next anchor member, the expansion of the ram is ceased, the free end of the ram rod is connected to the next anchor member, and the antenna arm is unlocked. The ram is then contracted to re-start the movement of the arm, and thus of the antenna, about the vertical axis.

[0007] Reversing this sequence will cause the antenna to be slowly rotated about its vertical axis in the opposite direction.

[0008] Since the movement of the free end of ram rod can be effected rapidly while the arms is locked, there is no significant interruption of the slow rotational movement of a tracking antenna. In fact, for large antennas used as solar collectors, for which the present invention was developed, the dimensions of the components of the solar energy collection arrangement are such that stepwise contraction of the hydraulic ram is normally used to rotate and reposition the antenna structure. This will be explained in more detail later in this specification.

[0009] Not only is such a rotational drive mechanism substantially less costly than the conventional drive motor and its associated accurately laid track with which the pinion driven by the drive motor engages, but the emergency "back up" arrangement for off-steering the antenna can be the same ram arrangement adapted to be driven by pressurised gas (for example, nitrogen) from a cylinder of the gas.

[0010] It will be appreciated that, as noted above, this mechanism for rotating a dish antenna can be used to rotate other bodies.

[0011] Thus, according to the present invention there is provided a mechanism for rotating a body (such as a large dish antenna for collecting solar energy) about an axis, said mechanism comprising

(a) an arm attached to or forming part of said body, and extending generally radially from said axis;

(b) a hydraulic ram having a ram cylinder and a ram rod actuated by hydraulic fluid within said ram cylinder, said ram cylinder being connected to said arm;

(c) a plurality of substantially equi-spaced anchor members fixedly mounted on a platform on which said body is mounted, said anchor members lying on a circle, or on an arc of a circle, the plane of said circle being orthogonal to said axis and the centre of said circle being on said axis;

(d) means for engaging the end of said ram rod which is remote from said ram cylinder with a selected one of said anchor members;

(e) substantially circular, or arcuate, guiding means for guiding said end of said ram rod from said selected ram anchor member to an adjacent anchor member;

(f) locking means for temporarily locking said arm in locations occupied by said arm in its rotational movement about said axis; and

(g) hydraulic control means for expanding and contracting said hydraulic ram.

[0012] For a better understanding of the present invention, an embodiment thereof will now be described, by way of example only, with reference to the accompanying drawings.

Brief Description of the Accompanying Drawings

[0013] Figure 1 is a perspective sketch of a dish antenna designed by the present inventors for the collection of solar radiation, for which the present invention was developed.

[0014] Figure 2 is a side elevational view of the antenna of Figure 1.

[0015] Figures 3, 4 and 5 are schematic drawings which illustrate how the mechanism of the present invention rotates a large body, such as the antenna of Figures 1 and 2, about an axis.

Detailed Description of the Illustrated Embodiment

[0016] The dish antenna 10 illustrated in Figures 1 and 2 was designed by the present inventors and has been assembled at The Australian National University, in Canberra, Australia. It comprises a dish 12 constructed using a number of reflecting dish segments or panels 31 which are mounted on a dish supporting frame 15. The dish 12 is a spherical reflector having a hexagonal periphery. The shorter edges of the hexagonal periphery are 21.8 metres long and its longer edges are 24.7 metres long. The dish has an aperture of 400 square metres. If this dish should focus the sun (which subtends an angle of about 0.5° at the earth) sharply, the sun's image would have a diameter of approximately 14cm. Such an image of the sun would create such a concentration of energy at the focus that most materials used in equipment to harness the sun's energy would be damaged. Thus the dish 12 is designed to form a "fuzzy" image of the sun, having an area of about five times the sharply focused image, at its focal region. A "receiver" 13 of the solar energy, which is supported by struts 21, is positioned at the focal region of the dish 12. In the solar collector built by the present inventors, the receiver 13 comprises a coiled tube which is used to generate high quality steam (that is, steam at high pressure and high temperature - although the temperature of the steam is limited by its application, for most steam turbines cannot accept steam at a temperature in excess of 500°C).

[0017] It is emphasised that the solar collector featured in Figures 1 and 2 is but one example of a rotatable structure with which the present invention may be used and the present invention is not limited in its application to solar energy collectors generally, or to antenna configurations which are similar to that illustrated in Figures 1 and 2.

[0018] The dish supporting frame 15 is pivotally connected by a horizontal tilt axis 14 to a base frame 11 of the antenna structure. The elevation of the line of sight 32 of the dish antenna is controlled by movement of the dish 12 and its support frame 15 about the tilt axis 14 using a hydraulic ram arrangement 16 which controls the movement of a sub-frame 17 that extends from the dish support frame of the solar collector antenna. However, any other suitable drive mechanism (such as a screw drive, a rack and pinion mechanism, or a recirculating ball mechanism) could be substituted for this tilting arrangement.

[0019] The base frame 11 of the antenna is mounted for rotation about a vertical axis 20, which is at the centre of a circular track 18. In conventional large antennas, the rotation of the main or base frame 11 about the axis 20 would be effected by drive motors, driving pinions which engage a circular track. The solar collector antenna constructed by the present inventors utilises a different form of frame rotating mechanism, constructed in accordance with the present invention.

[0020] Figures 3, 4 and 5 are schematic views, from above, of one implementation of the present invention. The body (for example, the base frame 11 of the antenna of Figures 1 and 2) to be rotated about an axis 82 is provided with an arm 81 which extends generally radially from the axis 82. The arm 81 may be an integral part of the body to be rotated. The cylinder 85 of a double acting hydraulic ram is connected to the arm 81 at or near its free end. The hydraulic ram is extended and the free end of the rod 86 of the ram is connected to an anchor member 85a. Anchor member 85a is one of a plurality of anchor members 85a, 85b, 85c, ... which are rigidly mounted on a circle centred at the axis 82. The hydraulic ram is contracted, and the action of moving the ram rod 86 into the ram cylinder 84 pulls the end of the arm 81 towards the anchor member 85a. Thus the body to which the arm 81 is attached (or of which the

arm 81 forms a part) is rotated in the direction of arrow 87 about the vertical axis 82.

[0021] At a predetermined contraction of the hydraulic ram, shown in Figure 4, the contraction of the ram ceases. At this point, the arm 81 is locked in its location and the end of the ram rod 86 which has been connected to the anchor member 85a is released from that anchor member. In some instances, it may not be necessary to lock or clamp the arm 81 in its location when the contraction of the ram ceases. However, the locking of the arm 81 is necessary when the body being rotated is a large dish antenna, because wind forces on the antenna dish and its supporting structure may cause the antenna to rotate in the opposite direction to arrow 87.

[0022] The hydraulic ram is then expanded. This expansion causes the end of the ram rod 86 to move along a generally circular guide 89 until it reaches a predetermined degree of expansion, shown in Figure 5, which occurs when the free end of the ram rod reaches the next anchor member 85b. At this point, the ram rod is connected to the anchor member 85b, the arm 81 is unlocked, and the contraction of the hydraulic ram begins again, to continue the rotation of the arm 81 in the direction of arrow 87.

[0023] If complete rotation of the body is not required, the anchor means 85a, 85b, 85c will normally be mounted on an arc of a circle and the guide or guiding means 89 will be, correspondingly, on an arc of a circle.

[0024] When the body to be rotated by this mechanism is a large dish antenna of the type illustrated on Figures 1 and 2, the "receiver" upon which the light from the sun is focused is larger than the sun's "fuzzy" image. Typically the image of the sun remains within the receiver's target zone for about 20 seconds, so that it is only necessary to adjust the position of the collector every 20 seconds or so, when the image is about to leave the receiver target zone. Using the arrangement illustrated in Figures 3, 4 and 5, it has been found that it is convenient to contract the hydraulic ram in steps, every 15 seconds. This is easily achieved by controlling the volume of fluid in each chamber of the hydraulic ram and does not require any feedback arrangement; the control of the position of the antenna's collector is achieved by merely controlling the amount of fluid pumped by a hydraulic motor. Furthermore, although the rotation of the arm 81 in the direction of arrow 87 is a very slow rotation, when the end of the ram rod has to be moved from one anchor member to the next anchor member, the ram can be driven at a relatively high speed, such that the time from reaching the end of travel and being disconnected from one anchor member to the time of being connected to the adjacent anchor member and commencing the next contraction of the ram is only about 15 seconds. Thus the time taken in moving the ram rod from one anchor member to the next does not result in the sun's image leaving the receiver. A further advantage of this rapid movement is that, if necessary, the ram can off-steer the collector by a substantial amount by engaging an anchor then fully contracting in one operation instead of in steps.

[0025] When the present invention is used with a large dish antenna, such as that illustrated in Figures 1 and 2, the anchor members are approximately equi-spaced and secured to a circular concrete track. Each anchor member typically comprises a stanchion with a plate member at the top of the stanchion, extending radially inwards. A hole or aperture in the plate member is adapted to receive a draw pin which is mounted for vertical movement at the end of the ram rod 86. When the draw pin and aperture are aligned, movement of the draw pin into the aperture secures the end of the ram rod to the anchor member. The draw pin assembly is mounted on a roller structure which carries the end of the ram rod 86 when the ram is expanding and the end of the ram rod is being moved from one anchor member to the next. A guide mechanism is required to guide the roller structure and ensure that the draw pin and the aperture in the plate member become aligned.

[0026] The operation of the body rotating mechanism which has been built by one of the present inventors, and which is used with the solar collector dish antenna featured in Figures 1 and 2, is controlled by a programmed microprocessor, which ensures that the line of sight of the collector dish of the antenna automatically tracks the sun each day.

[0027] When the present invention is included in a large solar energy collector, of the type illustrated in Figures 1 and 2, it is preferred that the support frame 15, on which the reflective panels 31 are mounted to from the dish 12, is constructed as a plurality of strut assemblies, each strut assembly comprising six rigid struts, connected at their ends to four nodes of the support frame to form a tetrahedral strut assembly. In addition, the support frame 15 will have a plurality of dish mounting points, each dish mounting point being at a respective one of the nodes of a strut assembly, the dish mounting points being located on the envelope of the shape of the dish.

[0028] The use of tetrahedral strut assemblies provides a strong and rigid, yet relatively light-weight, supporting frame for the dish of the antenna. Careful selection of the length of the struts in the various tetrahedral strut assemblies permits the mounting points for the dish, which are at respective nodes of the strut assemblies, to be positioned accurately in any required location. By having the mounting points at the envelope of the dish surface, the dish - or the elements which make up the dish - can be mounted on the support frame without the need for adjustment of the spacing between each mounting point and the dish or dish element. Thus the antenna design can be effected in a laboratory and provided the appropriate number and lengths of struts are supplied to the antenna site, the dish supporting frame can be assembled accurately, in situ, and the dish can be mounted on the frame and the antenna operated immediately.

[0029] Examples of the way in which tetrahedral strut assemblies may be joined together to construct such a large dish support frame are described in the specification of International patent application No PCT/AU93/00588, which is WIPO publication No. WO 94/11918.

[0030] In such a large solar energy collector, it is also preferred that the horizontal axis 14 about which the dish support frame 15 rotates is displaced a substantial distance from the major axis or line of sight 32. In the large solar collector illustrated in Figures 1 and 2, the axis 14 lies approximately midway between the centre of the surface 30 and its lowest outer edge 33. It will be appreciated that the stresses generated in the dish due to an offset axis of pivoting require a somewhat stronger dish support structure than would be the case with an axis of rotation at approximately the balance point of the dish and its support frame. The use of a dish supporting frame comprising tetrahedral strut assemblies provides such a frame, and allows it to be realised economically.

[0031] Positioning the pivot axis 14 away from the centre of the collector dish means that, when aligned at or near the horizon, only about one quarter of the diameter of the collector lies below the axis 14. Thus a lower base frame 11 may be utilised, to provide a further saving in materials and cost.

[0032] Offsetting the pivot axis 14 does not reduce the total height of the antenna when the collector dish is tracking near the horizon. Tracking near the horizon, however, occurs early in the morning and late in the afternoon, when winds are usually light, and will have little effect on a large dish with a nearly horizontal line of sight. Stronger winds are usually experienced during the middle of the day, when maximum energy is collected. At this time, the total height of an antenna with an offset pivot axis 14 is reduced substantially and the collector dish remains relatively close to the ground. While this in itself does not effect or collector efficiency, the reduction in overall height does reduce the wind loads on the structure when the wind is stronger than a light breeze. This is partly due to the reduction in the area of the antenna structure that is exposed to the wind, and partly due to the normal attenuation of wind near to the ground. One consequence of this is the possibility that the dish supporting frame may be made weaker and the antenna will still be operable in the same maximum wind speeds. However, it is preferably not to reduce the strength of the dish support frame, but to have the benefit of the ability of the antenna to be operated in higher wind speeds without the risk that the wind will generate loads on the antenna structure which will damage the structure.

[0033] Thus, the use of the off-set axis 14 feature firstly lowers the forces applied to the antenna structure, which allows continued operation in higher wind speeds, and secondly lowers the overall height when the collector is "parked", with its line of sight 32 vertical, so that wind loads and potential damage are reduced. The only disadvantage of an off-set horizontal axis is a slightly higher drive energy requirement, which must now support part of the weight of the dish. However, the increased efficiency of operation of a solar collector antenna and the lower costs of construction more than compensate for this.

[0034] Preferably, the other supporting structures used in the antenna illustrated in Figures 1 and 2, namely the base frame 11 and the back frame 25, are also constructed using tetrahedral strut assemblies.

[0035] Skilled engineers will appreciate that the embodiments of the present invention which are illustrated in the accompanying drawings and described above are examples only of realisations of the present invention, and that the invention is not limited to those embodiments.

Claims

1. A mechanism for rotating a body about an axis (82), said mechanism comprising

    (a) an arm (81) attached to or forming part of said body, said arm extending generally radially from said axis;
    (b) a hydraulic ram having a ram cylinder (84) and a ram rod (86) actuated by hydraulic fluid within said ram cylinder, said ram cylinder being connected to said arm (81);
    (c) a plurality of substantially equi-spaced anchor members (85a, 85b, 85c) fixedly mounted on a platform on which said body is mounted, said anchor members lying on a circle, or on an arc of a circle, the plane of said circle being orthogonal to said axis and the centre of said circle being on said axis;
    (d) means for engaging the end of said ram rod (86) which is remote from said ram cylinder (84) with a selected one of said anchor members;
    (e) substantially circular, an arcuate, guiding means (89) for guiding said end of said ram rod from said selected anchor member to an adjacent anchor member;
    (f) locking means for temporarily locking said arm in locations occupied by said arm in its rotational movement about said axis; and
    (g) hydraulic control means for expanding and contracting said hydraulic ram.

2. A mechanism as defined in claim 1, in which

    (1) said platform is the earth or a concrete pad mounted on the earth;
    (2) each of said anchor members is a stanchion affixed to said platform, said stanchion having a plate member extending radially inwards in relation to said circle or arc of a circle;

(3) said end of said arm (81) is supported by a carrier adapted to move over the surface of said platform; and
(4) said means for temporarily securing said end of said ram rod to an anchor member comprises means for temporarily connecting said end of said arm to said plate member.

3. A mechanism as defined in claim 1 or claim 2, including a programmed microprocessor for controlling the operation of said mechanism.

4. A mechanism as defined in claim 1, claim 2 or claim 3, in a solar collector having a large dish 12 comprising a plurality of reflecting elements (31) mounted on a dish support frame (15), said body comprising a base frame (11) on which said dish support frame is mounted, **characterised in that** said dish support frame comprises

(a) a plurality of strut assemblies, each strut assembly comprising six rigid struts, the ends of the struts being connected to four nodes of the support frame to form a tetrahedral strut assembly; and
(b) a plurality of dish mounting points, each dish mounting point being at a respective one of the nodes of a strut assembly, said dish mounting points being located on the envelope of the shape of the dish.

5. A mechanism as defined in claim 4, further **characterised in that** said dish support frame (15) is mounted on said base frame (11) at a pivot axis (14) which is offset relative to both the pointing axis (32) of said dish (12) and the axis of rotation (20) of said base frame (11).

6. A mechanism as defined in claim 5, in which said pivot axis (14) is located approximately mid-way between the pointing axis (32) of the dish support frame (15) and the edge (33) of the dish support frame.

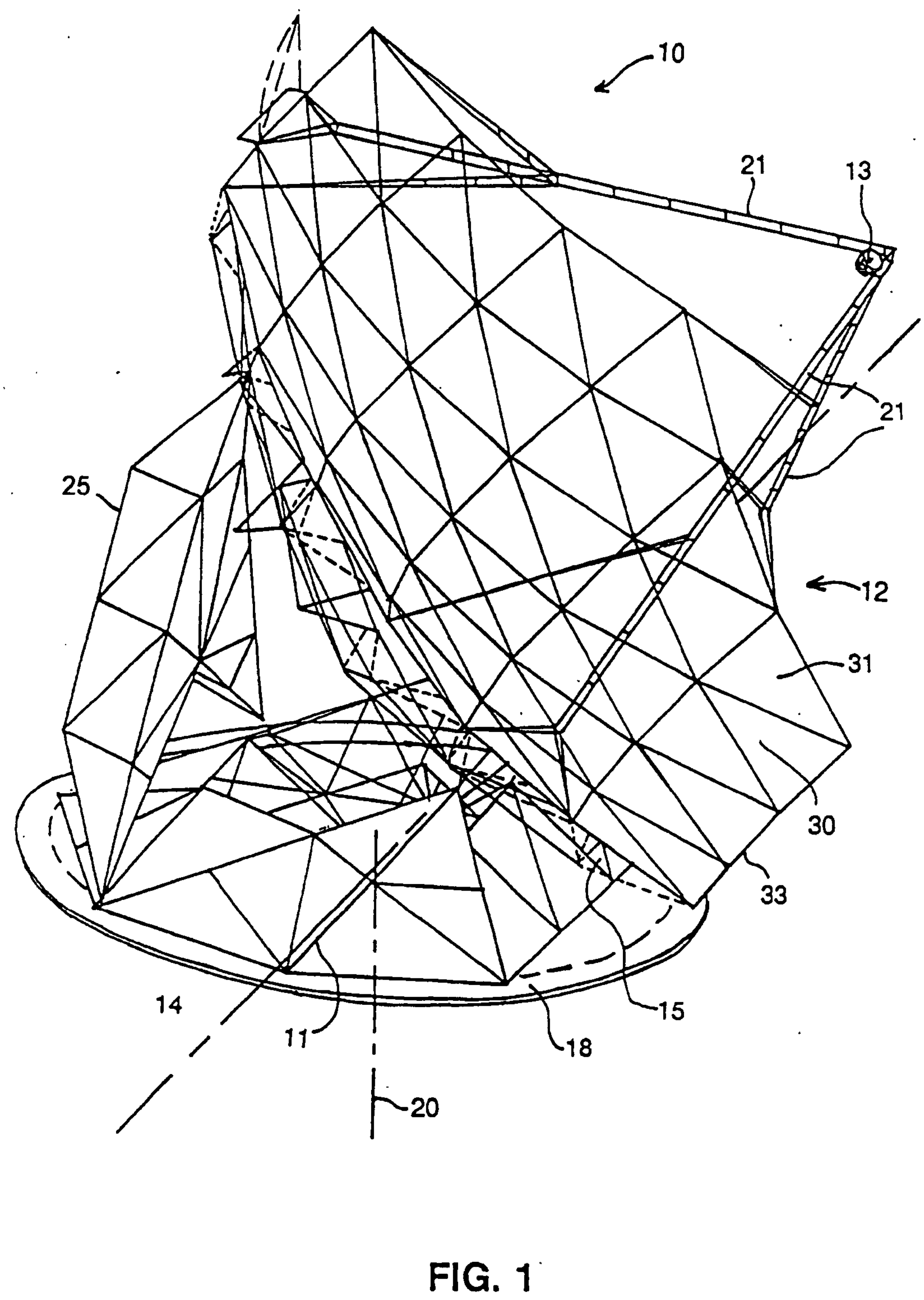

FIG. 1

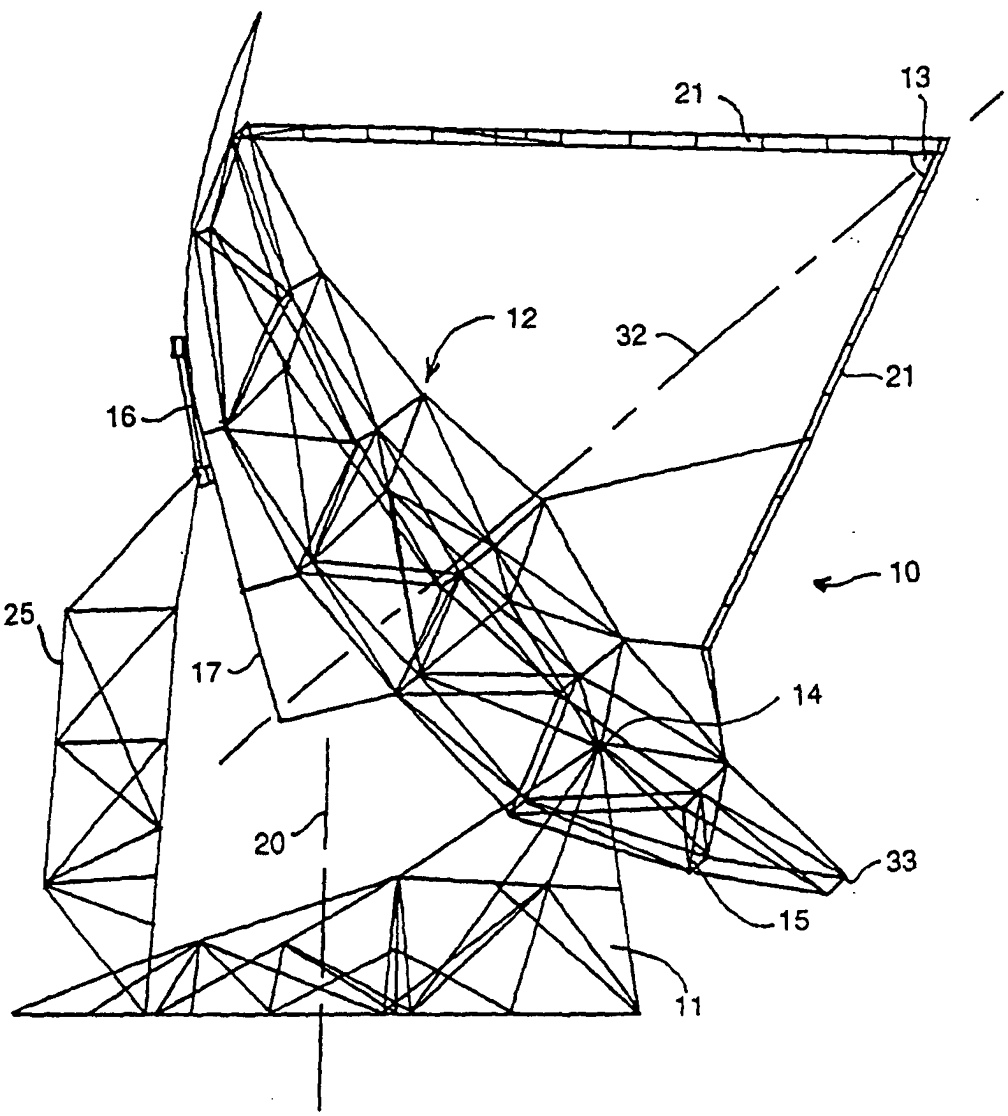

FIG. 2

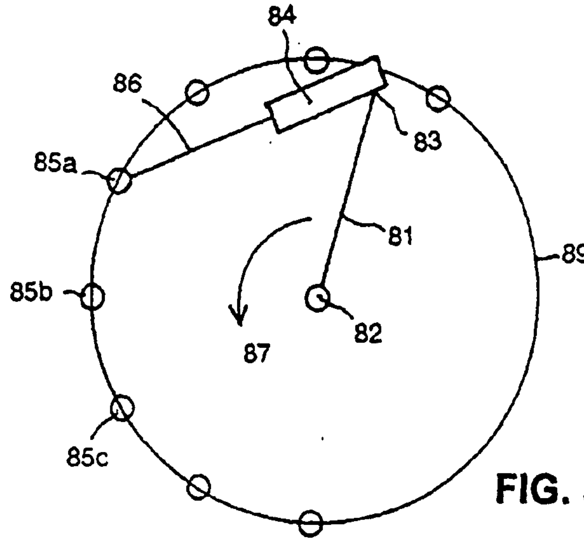

FIG. 3

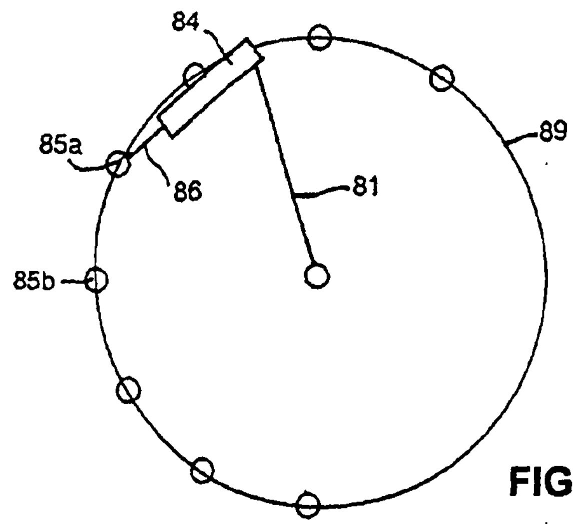

FIG. 4

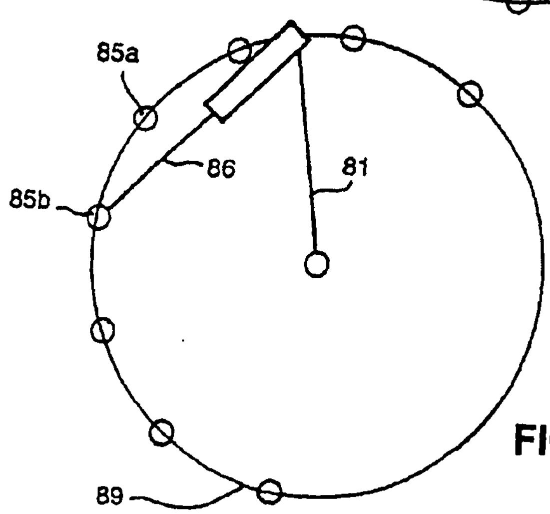

FIG. 5

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Acton, ACT 2601 (AU)

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(74) Representative:
Valentine, Francis Anthony Brinsley
REDDIE & GROSE
16 Theobalds Road
London WC1X 8PL (GB)

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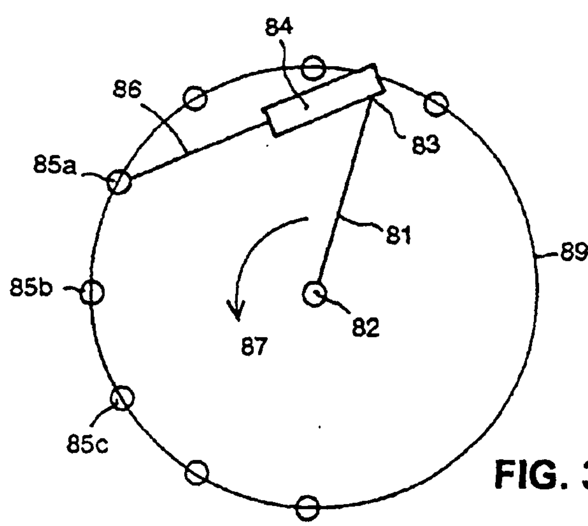

FIG. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 01 12 1066

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X Y	FR 1 294 993 A (MECANIQUE GENERALE DE L OUEST) 1 June 1962 (1962-06-01) * page 1, left-hand column, paragraph 1 - page 1, right-hand column, paragraph 1; figures 1,2 *	1 3	F15B11/12 F24J2/40 F15B15/06
X	DE 391 798 C (XAVER MATZINGER) 11 March 1924 (1924-03-11) * the whole document *	1	
A	FR 2 530 745 A (SALZGITTER AG) 27 January 1984 (1984-01-27) * page 3, line 1-32; figure 1 *	1,2	
A Y	DE 37 23 202 A (BOSCH GMBH ROBERT) 26 January 1989 (1989-01-26) * abstract; figure 1 *	1 3	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			F15B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	25 October 2002	Busto, M

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 01 12 1066

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25-10-2002

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